SP-F8: Transfer of Energy and Nutrients by Anadromous Fish Migrations

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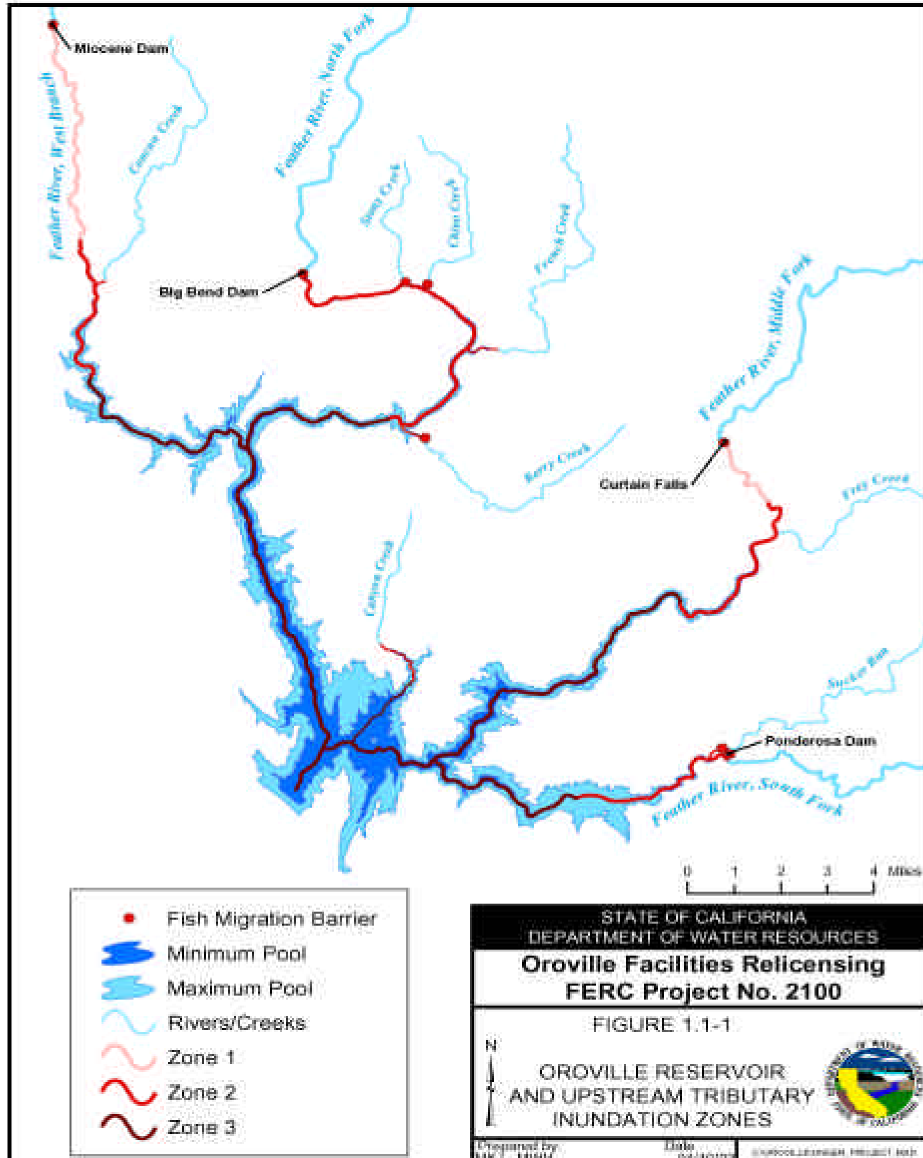
Need for Study

Project facilities currently prevent the upstream movement of anadromous fish, which affects transfer of marine-derived nutrients and organic matter to the tributaries upstream of the reservoir. Reduced nutrient transfer potentially results in a general decrease in productivity of the aquatic and terrestrial ecosystems of the upstream tributary basins.

Task Objectives

- Task 1: Document information regarding historical escapement of anadromous salmonids upstream of Oroville Reservoir.
- Task 2: Estimate potential escapement level for existing habitat conditions of tributaries upstream of reservoir.
- Task 3: Estimate amounts of nutrients and organic matter potentially supplied by salmonids to the tributaries.
- Task 4: Review nutrient transfer strategies to compensate for depleted anadromous salmonid populations and evaluate results and issues of implementation.

Study Area



Miocene Dam
Feather River, West Branch
Feather River, North Fork
Big Bend Dam
Feather River, Middle Fork
Curtain Falls
Ponderosa Dam
Feather River, South Fork
0 1 2 3 4 Miles
Fish Migration Barrier
Minimum Pool
Maximum Pool
Rivers/Creeks
Zone 1
Zone 2
Zone 3
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
Oroville Facilities Relicensing
FERC Project No. 2100
FIGURE 1.1-1
N
OROVILLE RESERVOIR
AND UPSTREAM TRIBUTARY
INUNDATION ZONES
Prepared by
MKJ - MWH
Date

Anadromous Salmonids as Nutrient and Organic Matter Source

- Anadromous salmon are allocthonous nutrient source.
- At least 95% of mass in Pacific salmon is derived from marine environment and transported to natal streams by adult salmon migrating upstream to spawn.
- Nutrients and organic matter released via excretion, egestion, gametes and, most importantly, carcasses of salmon.
- Smolts reverse the process, but their biomass reaching ocean is generally much less, so net transfer is from ocean to stream.
- Terrestrial animals, riparian vegetation and floods transport salmon-derived nutrients from stream to terrestrial ecosystem.
- Many anadromous salmonid streams and watersheds are oligotrophic and salmon spawning is a major nutrient source.

Task 1: Review information on historical escapement of anadromous salmonids upstream of reservoir.

- State agency reports
- Peer-reviewed literature
- Interviews with retired DFG, USFS staff and fishing guides

Historical Escapement Estimates

Period	Estimated Escapement	Source
1953-1959	1,000 – 4,000 spring-run	Fry 1961
1953-1962	0 –4,000 spring-run	Menchen 1966
Pre-project	5,200 spring-run	DFG 1960
Pre-project	2,300 fall-run	DFG 1960
Pre-project	2,000 steelhead	DFG 1960
1963-1966	296 – 3,362 spring-run	Painter 1977
1963-1966	416 – 914 steelhead	Painter 1977
Pre-project	1,718 spring-run	Sommer et al. 2001

Task 2: Estimate potential escapement levels given existing spawning habitat.

- Estimate surface area of habitat suitable for Chinook salmon spawning in upstream tributaries (Study SP-F3.1).
- Estimate typical densities of anadromous salmonid spawners from redd surveys.
- Extrapolate escapement estimate to unsurveyed stream reaches, including inundated zones.

Fall-run Chinook Spawning Density

River	Year	Mean Redd Density	Estimated Spawning Density	Source
Feather	2001	---	8,440	Cavallo 2003
Feather	1995	---	6,137	Sommer et al. 2001
Stanislaus	1999	2,462	4,924	Carl Mesick 2002
Stanislaus	2000	3,347	6,694	Carl Mesick 2002
Tuolomne	1988	214	856	Mierau 2003
Battle Creek	1989	554	1,108	Ward and Kier 1999
Columbia	1994	73	292	Visser et al. 2002
Columbia	1995	54	216	Visser et al. 2002

Potential Escapement

Surveyed Stream or Inundation Zone	Length (miles)	Estimated Escapement
West Branch	2.55	44 - 1,700
Middle Fork	0.68	78 – 3,037
South Fork	1.69	152 – 5,952
Total for Streams	4.92	274 – 10,689
Zone 1	8.39	467 – 18,228
Zone 2	23.90	1,331 – 51,924
Zone 3	40.71	2,267 – 88,445
Totals all Zones	73.00	4,065 – 158,597

Task 3: Estimate nutrients potentially supplied by anadromous salmonids in upstream tributaries.

- Estimate nutrient content of Pacific salmon.
- Estimate potential annual loading of nutrients upstream of reservoir as product of escapement biomass and nutrient content.
- Estimate corresponding nutrient concentrations from loading estimates, carcass nutrient loss rates and inflow data.

Nutrient Content (percent) of Salmon

Species	N	P	C	Reference
Sockeye	2.6	0.5	14.0	Mathisen et al. 1988
Sockeye	3.0	0.4	---	Mathisen et al. 1988
Sockeye	3.0	0.4	---	Schuldt & Hershey 1995
Sockeye	---	0.34	---	Larkin & Slaney 1997
Pink	2.6	0.35	---	Gende 2001
Unspecified	3.0	0.325	---	Stansby & Hall 1965

Annual Nutrient Loadings (pounds)

Surveyed Stream or Inundation Zone	Nitrogen	Phosphorus	Organic Carbon
Zone 1	364 – 16,405	46 – 2,734	1,961 – 76,558
Zone 2	1,038 – 46,732	130 – 7,789	5,590 – 18,081
Zone 3	1,768 – 79,600	221 – 13,267	9,521 – 374,469
Totals all Zones	3,171 – 42,737	396 – 23,790	17,073 - 666,107

Average Increases in Concentrations of Nutrients

Inundation Zone	Nitrogen (µg/L)	Phosphorus (µg/L)	Organic Carbon (µg/L)
Zone 1	0.21 – 9.65	0.01 – 0.80	1.15 – 45.04
Zone 2	0.61 – 27.49	0.04 – 2.29	3.29 – 128.31
Zone 3	1.04 – 46.82	0.07 – 3.90	5.60 – 218.55
Totals	1.87 – 83.98	0.12 – 7.00	10.04 – 391.90

Task 4: Review nutrient enhancement strategies and evaluate need for nutrient enhancement in upstream tributaries.

- Review results of experiments and programs to enhance nutrients in streams with depleted anadromous salmonids.
- Evaluate need for nutrient enhancement in the upstream tributaries.

Nutrient Enhancement Measures – Benefits and Costs

- Salmon carcasses: Readily available, optimal nutrient content, slow nutrient release, established and accepted - but costly to transport and disease and WQ issues.
- Fish carcass analogs: Easy to transport, no maintenance, no disease, optimal nutrient content, slow nutrient release - but costly to produce.
- Liquid fertilizers: Low cost, easy transport, no disease - but high maintenance, prone to spiking, may lack some nutrients, slow transfer up food chain, permitting issues.
- Slow-release fertilizers: Easy to transport, no maintenance, no disease, slow nutrient release - but costly, lack some nutrients, slow transfer up food chain, permitting issues.

Need for Nutrient Enhancement in Upstream Tributaries

- Streams in Pacific Northwest are considered nutrient-limited when TDP < 2 to 3 µg/L or DIN < 20 µg /L.
- Lowest detection limits in analyses for tributary water samples are 10 µg/L for TDP and 10 µg /L for DIN.
- About 70% of results from tributary sampling have been below detection limit.
- Current detection limits useful for evaluating eutrophication, but not for evaluating nutrient limitation.
- Cannot determine if tributaries need nutrient enhancement from information available.

Next Steps

- Evaluate productivity of upstream tributaries.
- If want to increase their productivity, determine limiting factors.
- To evaluate P or N limitation, use more sensitive sample analyses.
- If nutrient enhancement is needed, evaluate alternative methods for costs, benefits and suitability.

Recommendations for Evaluating Need for Nutrient Additions

- Evaluate potential limiting factors for fish production in the tributary ecosystems, including low P and/or N levels, low levels of organic matter, low availability of suitable habitat, high scouring flows and low light levels.
- Employ low-level detection methods for analyzing N and P of water samples from the tributaries. The methods should have detection levels of < 1 µg/L for SRP, 1 to 3 µg/L for TDP and 4 to 5 µg /L for DIN.

Recommendations for Implementing Nutrient Enhancement Program

- Evaluate costs and benefits of alternative enhancement methods and their suitabilities for each tributary.
- Target levels for carcass or fertilizer additions in Washington State Chinook salmon streams are 0.39 kg/m^2 carcass or 3 to 5 µg/L SRP and 15 to 50 µg/L DIN.
- Estimate average monthly discharge and bank-full stream width of West Branch and Middle Fork Feather River to compute amounts of nutrients and/or carcasses needed to to attain target nutrient levels.

Recommendations for Implementing Nutrient Enhancements (continued)

- Determine permitting requirements (e.g. NPDES) for nutrient additions.
- Monitor phosphorus, nitrogen and ammonia concentrations in the tributaries during and following nutrient or carcass additions to guard against eutrophication or toxicity.
- If carcass placement is considered for nutrient enhancement, assess the potential for fish diseases in carcasses obtained from the hatchery (or hatcheries).
- Employ a pilot program to test the alternative enhancement methods that seem most suitable for application in the tributaries.